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by

V. A. Atsyukovskiy

ABSTRACT: The need for maximum simplification of information devices, of measuring, computing, and control systems, and of conjugation units is pointed out. Evaluation of the information content of problems and of the information capacity of units is proposed. The concept of an information use factor for devices is introduced. It is shown that the mean information use factor for elements in information devices is extremely low, varying from 10^{-15} (for digital computers) to 10^{-2} (for automatic control systems). The question of simplification of the devices is raised, and several ways to simplify the devices are pointed out.

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The solution of any information problem requires the expenditure of a definite amount of information. /23 The amount will differ with the method used to solve the problem. However, the amount cannot be less than some number that depends on the indeterminancy of the magnitudes contained in the problem. This indeterminancy, expressed numerically, can be treated as the information content of the problem. Since the result of the solution to the problem is some set of output signals from the information device all solved information problems can be classified in terms of the indeterminancy these signals contain (Table 1).

TABLE 1

A priori known data	Indeterminancy
1.	Complete indeterminancy of all signal parameters.
2. Limitations on change in output signals (ranges, maximum rates, acceleration).	Probability characteristics. Class of laws. Concrete law. Parameters of law.
3. Probability characteristics of output signals.	Class of laws. Concrete law. Parameters of law.
4. Class of laws for the behavior of the output signals.	Concrete law and its parameters.
5. Law for the behavior of the output signals.	Some, or all the parameters of the law.
6. Complete information on output signals.	

* Numbers in the margin indicate pagination in the foreign text.

There rarely is a case of nothing at all being known about problems that must be solved in control measuring-computing complexes. However, the data known a priori, or assembled in the course of solving the problem, usually /24 are used inadequately, and this results in excess versatility of equipment and to making the equipment overly complex.

If we are to evaluate the correspondence between devices and the tasks these devices are to perform, we must compare the information content of these problems with the information possibilities provided by the devices.

Information theory takes the effective interval of indeterminancy, equal to

$$\Delta = e^{H(x/x_n)},$$

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as the bit of information. Here [illegible] is the entropy value of the error.

The value of the effective interval of indeterminancy coincides, in the case of a uniform distribution of the error, with the value of a quantum $\Delta = 4.146$* for normal distribution, and $\Delta = 1.57X_m$ for a sinusoidal error, where X_m is error amplitude.

Reproduction of signals F_1, F_2, ..., F_n with specified error ΔF_1, ΔF_2, ..., ΔF_n requires the reproduction of the parameters of the laws of change in the magnitudes P_{11}, P_{21}, ..., P_{n1}, ..., P_{nm}, with errors ΔP_{11}, ΔP_{21}, ..., ΔP_{nm}. The information content of the problem will be

$$I_{problem} = \sum_{k=1}^{m} \sum_{i=1}^{n} \log_2 \frac{P_{ik}}{\Delta P_{ik}}$$

where ΔP_{ik} is the effective interval of indeterminancy for the i^{th} parameter in the k^{th} system.

If parameter correction is available, the total amount of information, in terms of elapsed time, will be

$$I_{problem} = \sum_{k=1}^{m} \sum_{i=1}^{n} \log_2 \frac{P_{ik}}{\Delta P_{ik}} + \sum_{l=1}^{S} \sum_{k=1}^{m} \sum_{i=1}^{n} \log_2 \frac{\delta_e P_{ik}}{\Delta P_{ik}}$$

$\delta_e P_{ik}$ is the range of possible increase in the parameter;

S is the number of corrections made.

The information contained in the problem should be determined by minimization of the above expression, by selection of the correction interval, for example.

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* Quality of text and handwriting poor. Errors in deciphering fill-ins are regretted. Translator.

The effective interval of indeterminancy can be defined as

$$\Delta P_x = \frac{\Delta F_x}{\sqrt{n}} \cdot \frac{1}{\frac{\partial F_x}{\partial p_{ix}}} \cdot \frac{K_p}{K_F}$$

Here K_p and K_F are the entropy coefficients of the parameter and function, /25
respectively, equal to $\sqrt{3} = 1.73$ for uniform distribution, and to $\sqrt{\pi e/2} = 2.066$ for normal distribution.

The problem of selecting the direction at a plane with the preferred position in limits of tolerance of $2\sigma = 1°$ near the line of direction (normal distribution) for a range of selection of 360°, contains an amount of information

$$I = \log_i (360/4.14) = \log_i 174 = 7.445.$$

Another problem is one in which the law of change in the reproduced magnitude, a sine curve, is known, but the parameters of the law, the amplitude, frequency, phase, are unknown. Proceeding from the nondependency of these parameters, and from the equality of the size of the errors in the output signal, and in each of the parameters, we obtain

$$\Delta U = \Delta U_0 \sin(\omega t + \varphi) + U_0 \cos(\omega t + \varphi) \Delta\omega + U_0 \sin(\omega t + \varphi) \Delta t + U_0 \cos(\omega t + \varphi) \Delta\varphi$$

from whence the minimum amount of information needed to solve the problem is

$$I = \log_2 \frac{U_0}{4.14 \Delta U_0} + \log_2 \frac{\omega}{4.14 \Delta\omega} + \log_2 \frac{t}{4.14 \Delta t} + \log_2 \frac{\varphi}{4.14 \Delta\varphi}$$

When t = 1 second, f = 100 Hz, $\Delta u = 0.1\% u_o$, I = 63.2.

Let us look at some of the information characteristics of the devices.

The information capacity of a device can be defined as the number of bits of information the device is capable of producing in the form of its own output signals. The information yield is the amount of information the device actually produces, and is equal to the information content of the problems solved (handled) by this device. Therefore, the information use factor for the device should be understood to mean the ratio of the information yield by the device to its information capacity

$$\eta_{inf} = I_{yield}/I_{cap}.$$

W. Ross-Ashby represents redundancy in the form /26

$$P = 1 - I_{actual}/I_{consumed}$$

where

$I_{actual}/I_{consumed}$ is the actual information use factor.

Change in the output signal, within the limits of the effective interval of indeterminancy, must be taken as the bit of information generated by the device. The information capacity of the device then equals

$$I_{unit} = \sum_{i=1}^{n} \int_{0}^{f_i} f_i \, dt$$

where

n is the number of device outputs;

f_i is the limit frequency of generation of information for each of its outputs.

The information capacity of the device's components, or elements, can be found by using these same expressions, but then n is the total number of all outputs of all components, or elements, respectively, and f_i is the limit frequency of generation of information for each of the outputs of the components, or elements.

The information capacity of components and elements always is higher than the information capacity of the device as a whole. The information use factor for the components, or elements, since it is the ratio of the device's information yield to the information capacity of its components, or elements, always is lower than the device's information use factor. Generally speaking, the information use factor for a part always is less than, or, in the extreme case, equal to, the information use factor for the whole.

For example, in the case of a computer

$$\eta_{computer} \leq 1;$$

$$\eta_{component} = \eta_{component\ in\ the\ computer} \cdot \eta_{computer} \leq \eta_{computer} \leq 1;$$

$$\eta_{element} = \eta_{element\ in\ the\ computer} \cdot \eta_{component} \leq \eta_{component} \leq \eta_{computer} \leq 1.$$

The information use factor for the same elements will differ in different circuits, but at the same time the information use factor will decrease with increase in the number of elements in the case of complex systems. /27

TABLE 2

No.	Circuit Name	Circuit structure	Information capacity of device	Information capacity of elements	Information use factor
1.	Trigger				
2.	Shift register				
3.	Memory register				
4.	Counter				

Specifically, in the case of a binary counter, an increase in the number of elements results in an information use factor of

TABLE 3

n	1	2	3	4	5	6	7	8	9	10
γ	1	0,75	0,59	0,47	0,39	0,32	0,27	0,23	0,21	0,19

The information use factor makes it possible to determine the degree of underuse of the device and, as a result, the possibility, in principle, of using the device for other purposes, or the possibility of simplifying the device. At the same time, it should be pointed out that the information use factor for existing information devices is extremely low, particularly in the case of digital computers with an all-purpose structure used for a very narrow class of problems, but which, in principle, were designed to solve problems of the highest order of complexity. Table 4 lists tentative values for the information use factor for various devices mentioned on mobile objects.

The extraordinarily low information use factor necessitates raising the question of whether or not, at this stage of technical development, the basic trend in development ought to be in the direction of system simplification, rather than complication.

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TABLE 4

No.	Name of unit	Information use factor for device peak	Information use factor for device mean	Information use factor for element peak	Information use factor for element mean
1.	Measuring units	$10^{-2} \div 1$	$10^{-4} \div 10^{-2}$	$10^{-2} \div 1$	$10^{-5} \div 10^{-3}$
2.	Automatic regulation systems	$10^{-2} \div 1$	$10^{-3} \div 10^{-2}$	$10^{-2} \div 1$	$10^{-5} \div 10^{-2}$
3.	Communication lines	$10^{-3} \div 10^{-1}$	$10^{-4} \div 10^{-2}$	$10^{-4} \div 10^{-1}$	$10^{-5} \div 10^{-3}$
4.	Analog computers	$10^{-3} \div 10^{-1}$	$10^{-5} \div 10^{-3}$	$10^{-5} \div 10^{-3}$	$10^{-7} \div 10^{-4}$
5.	Digital-analog computers	$10^{-3} \div 10^{-1}$	$10^{-5} \div 10^{-3}$	$10^{-7} \div 10^{-3}$	$10^{-9} \div 10^{-6}$
6.	Digital computers	$10^{-4} \div 10^{-2}$	$10^{-7} \div 10^{-5}$	$10^{-10} \div 10^{-5}$	$10^{-15} \div 10^{-10}$

Table 5 lists some of the system simplification possibilities, as well as the effect they would have. System simplification will be accompanied by a reduction in system costs, increased dependability, and operational simplicity.

TABLE 5

Information device	Change in device or in scheme of use	Cost	Effect
Intersystem and intercomponent communications	Use of series codes instead of parallel codes	Complication of output and receiving registers	Reduction in number of wires by a factor of 10 to 20
	Introduction of switches for switching communication channels	Introduction of switches	Reduction in number of wires per object by a factor of 10 to 100
	Use of single-channel SKT [unident] in place of two-channel selsyns		Simplification of communications, of amplifiers, and reduction in wires
Measuring devices	Combining of measuring means and problems, processing of excess information	Additional calculations	Increase in accuracy with which problems are solved by a factor of 2 to 5 /29
	Use of one measuring device in sequence for various purposes	Introduction of switches	Reduction in number of measuring devices by a factor of 2 to 10
	Increase in time of transient processes		Reduction in power of the processing elements, reduction in weight
	Transfer of secondary processing to a centralized complex computer		Simplification of measuring devices, increased accuracy
Computers	Use of series structures instead of parallel	Reduction in speed	Reduction in number of elements by a factor of 1.5 to 5
	Reduction in number of digits, use of series-group calculations	Reduction in speed	Reduction in number of elements simplification of structure
	Use of calculations in increments instead of integrals		Reduction in number of elements simplification of structure
	Calculations made only when information appears	Introduction of operations to assess change in input	Freeing of computer from unnecessary calculations
	Specialization of structures for problems to be solved		Elimination of direct structural excesses

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